

13 January 1967

TECP 700-700
Materiel Test Procedure 5-2-501
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

TESTS OF LIQUID PROPELLANT SYSTEMS

1. OBJECTIVE

The objective of liquid propellant systems tests is to determine limitations and other characteristics which may affect liquid propellant systems operation.

2. BACKGROUND

The procedures outlines in this Materiel Test Procedure describe liquid propellant system tests which are applicable to missile systems. Because of the reliability requirements placed on liquid propellant systems, laboratory engineering tests and evaluations are performed.

The procedures in this MTP are not intended to be peculiar to testing specific liquid propellants systems. They intentionally were made general to provide coverage for various types of systems. Special procedures are detailed in the applicable specifications, manufacturer's instructions, or Missile Purchase Description (MPD's).

For a complete listing of terms, definitions and letter symbols applicable to liquid propellant systems, see references 4D, 4E and 4P.

3. REQUIRED EQUIPMENT

- a. Manufacturer's Instructions and/or Specifications.
- b. Static Firing and Non Firing Flow Test Facility as described in Appendix B.
- c. Hazard and Destruct Test Facility and Equipment as described in Appendix B.
- d. Propulsion System Component Test Facility, including:
 - 1) Pneumatic Test Facility as described in Appendix B
 - 2) Hydraulic Test Facility, as described in Appendix B
 - 3) Electrical Test Facility as described in Appendix B
- e. Firing and/or Control Console for the Missile System Under Test
- f. Applicable Missile Handling Dollies
- g. Applicable Nozzle Plug
- h. Cleaning Agent
- i. Applicable Flushing Agent
- j. Rust Inhibitor, when required
- k. Wax Preservative, when required
- l. Heat Lamps and Fans for air circulation; or
- m. Vacuum Dry-out Chamber (with an internal heat source)
- n. Fuel (gasoline, kerosene, etc.) and Flammable (scrap) or

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- o. Fuel oil and a sizeable flat container used as a burner for remote control.
- p. Lumber
- q. Pressurized Propellant Tanks/Pressurized Gas Tanks and Hypergolic Propellants or Non-Hypergolic Propellants
- r. Cal .30 Rifles and Machine Guns/Cal .50 Machine Guns/Cannon 40 mm or smaller with appropriate ammunition
- s. Transducers, Carrier Systems, and Recorders, as required
- t. Applicable Data Reduction and Conversion Equipment
- u. Vibration equipment as required in MTP 5-2-507
- v. Temperature chambers or shrouds (-85° to 125°)
- w. Motion picture camera and film
 - 1) 128 Frames per second
 - 2) 1000 Frames per second
 - 3) 6000 Frames per second
- x. Thermocouples and Strip Chart Recorders, as required
- y. Sound Level Meters or Pressure Gauges
- z. Shock Wave Blast Indicators

4.

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- R. Manual for Handling Missile Propellants, Pan American World Airways, Guided Missiles Range Division, Patrick Air Force Base, Florida, 15 September 1958.
- S. MTP 5-2-506, Shock Test Procedures.
- T. MTP 5-2-507, Vibration Test Procedures.
- U. MTP 5-2-594 High Temperature Tests
- V. MTP 5-2-583, Low Temperature Tests

5. SCOPE

5.1 SUMMARY

Tests of liquid propellants systems are summarized as follows:

a. Static Firing Tests

A series of tests conducted to determine the missile liquid propellant systems performance while being subjected to a prefiring, firing, and post firing operational environment.

b. Nonfiring Flow Tests

A series of tests similar to the prefiring static tests except that water or some inert fluid is used instead of the normal propellant liquid to allow close observation of the system or systems components under test.

c. Hazard and Destruct Tests

A series of tests conducted to determine the liquid propellant system's response when subjected to open flame fire, gunfire, and hypergolic propellant spillage.

d. Propulsion System Components Tests

A series of tests conducted on liquid propellant system components to determine reliability and response of pneumatic, hydraulic, and electrical components.

5.2 LIMITATIONS

None

6. PROCEDURE

6.1 PREPARATION FOR TEST

6.1.1 General

a. Personnel shall review all available pertinent manufacturers instructions and/or specifications for the system to be tested, determine the test facilities, and select the required test equipment (operating instructions shall be available).

b. The operator of the test equipment shall be familiar with the equipment, and shall comply with pertinent operating instructions.

c. Assure that a log folder is prepared for each liquid propellant system in order that pertinent information shall be recorded during the test.

6.1.2 Instrumentation

Data shall be recorded on magnetic tape, oscillograph and strip chart records depending upon the frequency response and accuracy specifications of required data.

Selection of the required transducers, carrier systems, recorders, conversion and reduction equipment shall be determined by the individual specifications and test requirements.

NOTE: Because of the expensive nature of liquid propellant tests, multiple, parallel data acquisition systems for critical data are required so that loss of a single channel shall not invalidate the test. (The number of data channels can run into the hundreds for a single firing test).

6.2 TEST CONDUCT

6.2.1 Static Firing Tests

6.2.1.1 Prefiring Operations

Prefiring operations shall be performed prior to conducting the static firing tests. These operations, which establish that all systems and components are operational, shall be performed in the applicable laboratory, when possible. Prefiring operations consist of the following:

6.2.1.1.1 Visual Inspection - The liquid propellant and its shipping containers shall be visually examined as follows:

a. The external conditions of the container shall be examined for indications of rough handling during transit, and observations recorded.

b. Record the pressure of pressurized containers and condition of the humidity indicator.

c. Remove the motor from the container, place it in its handling dolly and visually examine it for damage.

6.2.1.1.2 Pneumatic Leak Check - Seal and pressurize the test engine and perform the following checks:

NOTE: A flow system that terminates at the combustion chamber shall require a nozzle plug for sealing. Check that the plug is correctly installed so that the pressure upstream of the plug shall seal the chamber.

a. Check all joints for leakage with a soap and water or suitable leak detection solution.

NOTE: 1. The surface where the injector plate mounts to the head of the combustion chamber cylinder is a critical leakage area. (This surface usually is of a large diameter and the joint is sealed by means of a gasket or "o" ring. Leaks can be dangerous as liquid propellants frequently cause burns or fires).

2. Leak specifications on this joint shall be checked to determine the leakage tolerances, particularly when using hypergolic propellants.

b. Closely examine all gasket contact surfaces and tube flares prior to final assembly and record any damage.

NOTE: This step is required particularly if on a flange type or tube flare joint it has been necessary to exceed the torque specifications to stop a leak. Joints which pass leak tests without exceeding torque specifications need not be broken for examination.

c. Record the location of any leaks.

6.2.1.1.3 Functional Checks - Functional checks shall be performed in a laboratory to discover faulty components; they are the final operational check on a liquid propulsion system to ascertain that all operating components conform to specifications.

The following procedures shall be performed during functional checks:

a. Connect a control console similar to that used in the actual firing of the propulsion system.

b. Connect the test unit to the appropriate pressure supply and electrical systems.

c. Operate the system by following the specified sequence of events indicated on the test item's check specification sheet.

d. Record critical timing, automatic timing, regulated pressure feeds to various areas, time of opening and closing of valves, etc.

e. Record all faulty components discovered and all corrections and replacements needed.

NOTE: Prior to mounting the test engine to the test stand all faulty components shall be corrected or replaced.

6.2.1.2 Preparation for Firing

6.2.1.2.1 Cleaning and Purging - Carefully clean all parts of the system which

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will handle the liquid propellants and remove all grease, dirt, moisture or any other combustible foreign matter. (See References 4K and 4L).

6.2.1.2.2 Mounting - The engine shall be mounted as follows:

- a. Secure the engine thrust frame to the static test stand thrust frame.
- b. Connect all propellant, gas, instrument and electrical systems.

NOTE: Exercise extreme caution when connecting the test facility to the motor, ensuring that all lines are flexible so that thrust movement is unhampered.

- c. Repeat the procedures of paragraph 6.2.1.1.2.

6.2.1.2.3 Final Checkout and Fueling - Firing can be accomplished after completion of the following steps.

- a. Accomplish a complete check on all mechanical, pneumatic, and electrical systems between the engine and the instrument and control room (automatic control console).
- b. Charge the system with propellants up to main valves.
- c. Pressurize tanks.

NOTE: Liquid propellants are extremely hazardous. When working with liquid propellants, operating personnel shall wear full protective clothing and breathing apparatus as protection against highly toxic fumes and to prevent severe burns. (See References 4A, 4B and 4C).

- d. Perform, as applicable, a chemical analysis on the propellants and gas generants.

6.2.1.2.4 Flow Tests - The nonfiring flow described in paragraph 6.2.2 shall be conducted when directed during the prefiring operations to check propellant and pressure system performance.

6.2.1.3 Firing Operations

At the completion of prefiring operations, paragraphs 6.2.1 through 6.2.1.2.4 perform the following:

- a. Clear all personnel not required for placing an igniter or making final regulator settings to the control center.
- b. Prepare a motion picture camera to obtain complete camera coverage during firing operations.
- c. Insure the correct, short, countdown program is programmed into the automatic control console.
- d. Insure adequate manual control in the event of a malfunction.

NOTE: Should two or more firing operations be planned for the engine under test the following procedures shall be performed after each firing operation:

1. The engine shall undergo the appropriate post operation procedures of paragraph 6.2.1.4 less steps f, g, and h.
2. The engine shall undergo the procedures of paragraphs 6.2.1.2.1 and 6.2.1.1.2.
3. The engine shall receive a final checkout and be refueled and be subjected to flow test as described in paragraphs 6.2.1.2.3 and 6.2.1.2.4.
4. Repeat firing operations under the required conditions.

6.2.1.3.1 Ambient Firing Tests - Firing tests shall be conducted under ambient temperature conditions as follows:

- a. Commence countdown.
- b. Commence camera coverage.
- d. Record the following during the firing operation:
 - 1) Chamber pressure versus time
 - 2) Chamber temperature versus time
 - 3) Fuel and oxidizer flow rates
 - 4) Fuel and oxidizer tank pressures
 - 5) Fuel and oxidizer temperatures
 - 6) Flow system pressure drops
 - 7) Turbine speed (if applicable)
 - 8) Pump speed (if applicable)
 - 9) Injector pressure
 - 10) Critical times for the operation of valves, regulators, pumps, etc.
 - 11) Dew point of pressurizing air or gas (for pressure fed systems)

NOTE: The measurement may be done either before (paragraph 6.2.1.2.4) and/or continuously during firing. Continuously during firing is necessary in the event of regulator malfunction to assess the cause, ice or some other fault.

- 12) Thrust versus time.
- 13) Operating time
- 14) Temperature of jet vanes or other thrust vectoring devices
- 15) Flow rates of injectants for gas or liquid injection thrust vectoring control.
- 16) Components of thrust (as required)
- 17) The date the test was conducted
- 18) All test settings at which tests are conducted

6.2.1.3.2 Vibration Testing - Repeat paragraph 6.2.1.3.1 with the test item undergoing vibration as described in MTP 5-2-507.

NOTE: The effects of rough handling and transportation on liquid propulsion systems are determined by subjecting the system to applicable shocks and vibrations described in MTP 5-2-506 and 5-2-507.

6.2.1.3.3 Extreme Temperature - High and low temperature tests shall be

conducted as follows:

- a. High Temperature - Repeat paragraph 6.2.1.3.1 with the test item undergoing high temperature extremes as described in MTP 5-2-594.
- b. Low Temperature - Repeat paragraph 6.2.1.3.1 with the test item undergoing low temperature extremes as described in MTP 5-2-583.

6.2.1.4 Post Firing Operations

- a. Purge the flow system immediately after the completion of firing.
- b. Dismount the engine and remove it to the laboratory or assembly facility.
- c. Flush the complete engine if it has a pump system using hydrogen peroxide for the gas generant
- d. For nonhazardous propellants:
 - 1) Clean and dry the engine

NOTE: Drying can be accomplished by the use of heat lamps with circulating clean dry air, but the best results shall be obtained by placing the entire engine in a vacuum dry-out chamber with an internal heat source. Heat control and drying time are critical as gaskets and "o" rings can be damaged by excessive heat.

- e. For hazardous propellants (i.e. acid/aniline):

- 1) Remove all combustion residue from the inner surfaces of the chamber and ejector.
- 2) Completely flush and decontaminate all fuel and oxidizer passages of the engine.

NOTES: 1. Some disassembly of lines shall be necessary if there is a possibility of propellants being trapped in bends or valves.

- 2. The flushing agent shall be determined by the type of propellant used in the firing.

- 3) Clean and dry the engine.

f. Put the specified rust inhibitor in the cooling jacket of the motor when required.

g. Apply a coat of wax preservative on the inner surface of the chamber when required.

NOTE: The injector ports shall be considered to be critical since they are precision machined and are the primary control of fuel and oxidizer mixing in the chamber.

- h. Package the engine for shipping.

6.2.2 Nonfiring Flow Tests

Nonfiring flow tests shall be conducted with water or some inert fluid to determine the operating characteristics of various components and pressure drops at various points in the system.

NOTE: Safety requirements pertaining to hazardous propellants shall be relaxed during nonfiring flow tests, as hazardous propellants shall not be used.

a. The prefiring procedures outlined in paragraph 6.2.1.1 shall be followed for nonfiring flow, except that usually water or some nonhazardous fluid is used.

NOTE: Nonfiring flow tests can be conducted on the entire propulsion system or only on the motor.

b. Data shall be collected and recorded as described in paragraph 6.2.1.3.1.

c. Record all data related to the physical properties of the working fluid.

d. Make corrections for differences in specific gravity and viscosity between the working fluid (water or some inert fluid) and the missile propellants.

6.2.3 Hazard and Destruct Tests

a. Set up instrumentation to obtain blast data as follows:

- 1) Sound pressure level by means of pressure gauges to measure blast pressure (psig) or sound level meters capable of measuring decibels referenced to $0.0002 \text{ dynes/cm}^2$
- 2) Shock wave propagation by using ultra high speed (6,000 frames per second) cameras for blast wave time-of-arrival measurements.
- 3) Temperature, when required

NOTE: Sound pressure levels, shock wave propagation, and temperature measurements shall be taken in a radial array (increments no larger than 45°) at distances specified in the test items test plan.

b. All tests shall be conducted in accordance with the safety provisions and quantity distance tables outlined in reference 4C of this MTP.

c. Both high speed (1,000 frames per second) and normal (64 to 128 frames per second) shall be provided, if possible, during the conduct of hazard and destruct tests.

NOTE: These tests involve extremely hazardous conditions. Exercise good safety practices during the conduct of these tests.

6.2.3.1 Open Flame Fire Test

This test shall be conducted only on the filled propellant tanks to determine the severity of fire or explosions that might result from storage or shipping fires.

a. Prepare the test tanks for burning by either of the following methods:

1) Using wood scrap:

- a) Place fuel, lumber and flammable scrap, around the test tank
- b) Spread fuel oil on the lumber

2) Without wood scrap:

- a) Place the test item on a flat container
- b) Feed fuel oil to the test site by pump or gravity feed, from an isolated storage vessel.

b. Ignite the combustibles by a remotely controlled ignition device

NOTE: Sufficient combustibles shall be used to insure burning for 30 minutes

c. Record the following:

- 1) Flame temperature of fire
- 2) Time from fire ignition to propellant ignition
- 3) Duration of propellant fires
- 4) Blast data
- 5) Date of test

NOTE: In most cases tank rupture occurs and flaming propellant is scattered about. Detonation is possible and sometimes occurs.

d. Prepare a fragment map.

6.2.3.2 Gunfire Test

The objective of this test shall be to determine the extent of damage to a propulsion system, an entire missile, or group of missiles, when one such system is exposed to gunfire.

NOTE: Conditions under which the test is conducted may vary.

a. The test may include the following:

- 1) Filled and pressurized propellant tanks
- 2) Pressurized gas tank
- 3) Hypergolic propellants
- 4) Nonhypergolic propellants

NOTE: The most extensive damage will probably occur when both tanks of a hypergolic propellant pair are pierced; although similar results can be expected if after piercing nonhypergolic propellant tanks the resulting spillage becomes ignited.

b. Simulate possible enemy actions by using one of the following:

- 1) Cal .30 rifles and machine guns at various ranges up to 500 yards with ball, armor piercing and tracer ammunition.
- 2) Cal .50 machine gun in single or automatic fire
- 3) 40 mm cannon or smaller

c. The weapon used shall be fixed boresighted, and equipped for remote control.

d. Motion picture coverage shall be required

e. Record the following:

- 1) The time from firing the weapon to initial reaction of the propellant tanks
- 2) Blast data
- 3) Date of test

f. Prepare a fragment map of the area

6.2.3.3 Hypergolic Propellant Spillage Test

This test is conducted to determine the extent of fire or detonation when quantities of hypergolic propellants are quickly spilled (dumped) so that they combine in a sump.

a. Place the propellant in tanks of the same capacity as those on the system, with full open ends.

b. Ensure that there shall be no restrictions in flow when the tanks are tipped.

c. Mount the tanks so that when the releasing mechanism is triggered, both tanks will tip and dump their contents into the sump.

NOTE: The results of this test will usually be instant ignition or detonation, but ignition is sometimes delayed due to temperature of the propellants.

d. Install a remote controlled ignition system in the sump to ensure that spilled propellants shall be burned.

e. Motion picture photographic coverage of the events shall be accomplished.

f. Record the following data:

- 1) Temperature of propellants before test
- 2) Flame temperature of resulting fire
- 3) Blast and temperature data at various distances from the test on a radial array
- 4) Meteorological data as well as movement and dispersion of any vapor cloud which may be formed
- 5) Time from spill to deflagration or detonation of the propellants
- 6) Date of test

6.2.4 Propulsion System Component Test

Propulsion system component tests consist of pneumatic testing, hydraulic testing and electrical testing of the propulsion system components.

a. The following data shall be recorded for each propulsion system component test

- 1) The date the test was conducted
- 2) All test settings at which tests are conducted

6.2.4.1.1 General - The following procedures shall be performed during the testing of the pneumatic or pneumatic actuated components

a. Carefully control the dew point and purity of supply of gas as these are critical for many components.

NOTE: Some pneumatic tests are hazardous due to the presence and handling of high pressure gas.

b. Precautions shall be taken to prevent injury to personnel or adjacent equipment in case of rupture and/or malfunction of the test item.

c. Simple, inexpensive, blast containers shall be fabricated to meet safety requirements.

d. Immediately and thoroughly dry out any moisture introduced into a component.

NOTE: The introduction of grit, or other impurities, or moisture may cause malfunction and result in abortion of a flight.

6.2.4.1.2 Flow Regulators - Flow regulators shall be pneumatically tested as follows:

a. Connect and load the flow regulators on the bench in the same manner as they shall be in the missile.

b. Simulate the receiver vessel as closely as possible or use actual missile components if the flow regulators operate to pressurize a vessel or a propellant tank.

NOTE: The regulator may be adjusted through its entire range, set at a particular setting or simply checked at the factory adjustment depending upon the test requirements.

c. Start the gas flow after the regulator is connected in its system.

d. Record applicable pressures, flows and times.

e. Repeat tests five times to ensure repeatability when testing the pressure regulation. Check regulators against creep under no flow conditions if applicable.

f. Record the following data:

- 1) Regulator setting
- 2) Test gas properties
- 3) Upstream and downstream pressures versus time
- 4) Time duration of regulated pressure
- 5) Gas flow rates (may be measured or calculated)

6.2.4.1.3 Propellant Valves - Some propellant valves are pneumatically operated. These shall be tested for proper functioning of the valve operating mechanism, timing, and operating sequence of valves controlling two propellants in

opening, closing, and throttling actions. Other information such as flow rate and pressure drop at the various positions shall be determined by simulating propellant flow simultaneously with the hydraulic flow equipment. The following data shall be recorded:

- a. Operating pressure versus valve position
- b. Opening and closing time delays
- c. Propellant flow rate
- d. Upstream pressure
- e. Downstream pressure
- f. Physical properties of propellants

6.2.4.1.4 Relief and Safety Valves - These valves shall be checked on the pneumatic bench to determine or set relief pressure and determine blow-down range. The following procedures apply to the testing of relief and safety valves.

- a. Establish precise flow requirements for exhaust valves to obtain bleed-off in a specified time or at a specified rate.
- b. Use actual missile components for the entire function or simulate all components as closely as possible.
- c. Record the following data:
 - 1) Initial and final pressures
 - 2) Upstream pressure versus time
 - 3) Downstream pressure versus time (if applicable)
 - 4) Physical properties of exhausting gas

6.2.4.1.5 Servo Mechanism (gas operated) - Servo mechanisms shall be tested as follows to ensure that volume and pressure of delivered gas is sufficient for the required activating strokes and the linkage mechanism is free from excessive friction.

NOTE: Some servo mechanisms may be subjected to elevated temperatures by the exhaust flames.

- a. Monitoring in static or flight tests shall be usually required for servo mechanisms operating jet vanes.
- b. Mount the servo mechanism on the pneumatic bench in a manner which simulates its mounting in the missile.
- c. Operate it throughout its entire range
- d. Record the following data:
 - 1) Gas properties and pressures
 - 2) Mechanical loads
 - 3) Time delays
 - 4) Full range functioning time

6.2.4.2 Hydraulic Tests

Hydraulic tests consist of such tests as leakage, flow characteristics, valve timing, response timing, life and cycle endurance, pump performance, check and relief valve characteristics, and calibration of flow measuring instruments.

All these tests shall be conducted on the hydraulic flow bench for single components or complete missile piping systems.

6.2.4.3 Electrical Tests

The electrical tests generally consist of functional checks and endurance tests on components such as relays, solenoids, switches instruments, signal devices, electro-mechanical servo mechanisms, and similar missile equipment.

Specific equipment requirements for component tests shall depend on the components to be tested and the test objective.

6.3 TEST DATA

6.3.1 Test Conduct

6.3.1.1 Static Firing Tests

6.3.1.1.1 Prefiring Operations - Data shall be recorded during prefiring operations as follows:

- a. The following data shall be recorded during the visual inspection:
 - 1) Any signs of rough handling
 - 2) The pressure of the container (if it is a pressurized type).
 - 3) Condition of humidity indicator if applicable.
 - b. The following data shall be recorded during a pneumatic leak check:
 - 1) Any damages found when inspecting flange type or tube flare joint
 - 2) Location of any leaks
 - 3) Action taken to correct leaks, as applicable, to include final torque values
 - c. Record the following data during functional checks:
 - 1) Control timing, automatic timing, regulated pressure feeds to various areas, time of opening and closing valves, etc.
 - 2) All faulty components discovered and any replacements or corrections needed
 - d. Record the chemical analysis of the propellants and gas generators (as applicable)
- 6.3.1.1.2 Firing Operations - The following data shall be recorded during firing operations:
- a. Chamber pressure in psi versus time in seconds
 - b. Chamber temperature in °F versus time in seconds
 - c. Fuel and oxidizer flow rates in pounds per second
 - d. Fuel and oxidizer tank pressures in psi

- e. Fuel and oxidizer temperatures in °F
- f. Flow system pressure drops in psi
- g. Turbine speed (if applicable) in rpm
- h. Pump speed (if applicable) in rpm
- i. Injector pressure in psi
- j. Critical times for the operation of valves, regulators, pumps,
etc. in seconds
- k. Dew point of pressurizing air or gas (for pressure fed systems)
in °F
- l. Thrust in pounds-force versus time in seconds
- m. Operating time in seconds
- n. Temperature of jet vanes or other thrust vectoring devices in °F.
- o. Flow rates of injectants for gas or liquid injection thrust
vectoring control in pounds per second
- p. Components of thrust (as required) in pounds-force
- q. Motion picture coverage of the test
- r. The date the test was conducted
- s. All test settings at which tests are conducted

6.3.1.2 Nonfiring Flow Tests

The following data shall be recorded for nonfiring flow tests:

- a. Data shall be collected and recorded as described in paragraph 6.3.1.1
- b. The physical properties of the working fluid shall be recorded.

6.3.1.3 Hazard and Destruct Tests

6.3.1.3.1 Open Flame Fire Test - The following shall be recorded or prepared:

- a. Record the date of the test.
- b. Record the flame temperature of fire in °F
- c. Record the time from fire ignition to propellant ignition in
seconds
- d. Record the duration of propellant fires in seconds
- e. Prepare blast data graphs of the following:
 - 1) Sound level pressure, in psi or decibels versus distance from the blast area for specified distances at measured angles.
 - 2) Shock wave propagation, in feet per second, as determined from ultra high speed cameras, versus distance from the blast area for specified distances at photographed angles.
- f. Prepare a fragment map, if required.

6.3.1.3.2 Gun Fire Tests - The following data shall be recorded or prepared:

- a. Record the date of test
- b. Record the time from firing the weapon to initial reaction of the propellant tanks, in minutes.
- c. Prepare blast data graphs of the following:

- 1) Sound level pressure, in psi or decibels versus distance from the blast area for specified distances at measured angles.
- 2) Shock wave propagation, in feet per second, as determined from ultra high speed cameras, versus distance from the blast area for specified distances at photographed angles.

d. Prepare a fragment map, if required.

6.3.1.3.3 Hypergolic Propellant Spillage Tests - The following shall be recorded or prepared:

- a. Record the date of test
- b. Record the temperature of propellant before the test in °F.
- c. Record the temperature of resulting fire in °F.
- d. Record the time from spill to deflagration or detonation of the propellants in seconds.
- e. Meteorological data as well as movement and dispersion of any vapor cloud which may be formed.
- f. Prepare blast data graphs of the following:
 - 1) Sound level pressure, in psi or decibels versus distance from the blast area for specified distances at measured angles.
 - 2) Shock wave propagation, in feet per second, as determined from ultra high speed cameras, versus distance from the blast area for specified distances at photographed angles.
 - 3) Temperature, in °F versus distance from the blast area for specified distances at measured angles.

6.3.1.4 Propulsion System Component Tests

The following data shall be recorded for each propellant system component test:

- a. The date the test was conducted
- b. All test settings at which tests are conducted

6.3.1.4.1 Flow Regulators - The following data shall be recorded for the pneumatic tests of flow regulators:

- a. Regulator setting
- b. Test gas properties
- c. Upstream and downstream pressures in psi versus time in seconds
- d. Time duration of regulated pressure in seconds
- e. Gas flow rates may be measured or calculated in pounds per second
- f. Regulator creep, under no load conditions, when applicable

6.3.1.4.2 Propellant Valves - The following data shall be recorded for the hydraulic tests of propellant valves:

- a. Operating pressure in psi versus valve position in inches
- b. Opening and closing time delays in seconds
- c. Propellant flow rate in pounds per second

- d. Upstream pressure in psi
- e. Downstream pressure in psi
- f. Physical properties of propellants

6.3.1.4.3 Relief and Safety Valves - The following data shall be recorded in pneumatic tests of relief and safety valves:

- a. Initial and final pressures in psi
- b. Upstream pressure in psi versus time in seconds
- c. Downstream pressure in psi versus time in seconds (if applicable)
- d. Physical properties of exhausting gas

6.3.1.4.4 Servo Mechanisms - The following data shall be recorded during pneumatic tests of servo mechanisms:

- a. Gas properties and pressures in psi
- b. Mechanical loads in pounds-force
- c. Time delays in seconds
- d. Full range functioning time in seconds

6.4 DATA REDUCTION AND PRESENTATION

The data reduction and presentation normally shall consist of reducing the data from instrument indications and physical measurements to digital, tabular form which permits comprehensive analysis and evaluation. References 4F, 4G, 4K, and 4M describe data analysis procedures and methods of developing equations used in relating the various parameters associated with overall liquid fueled rocket propulsion system analysis.

Prepare a log folder for each liquid propellant system tested and enter all test data. The charts, graphs, and conversion calculations shall become a permanent part of the log. It is important that the log for each test be complete, accurate, and up-to-date as these logs may be used for future liquid propellant system analyses.

The test evaluation shall be limited to comparing the test results to the applicable specifications and to the requirements imposed by the intended usage. Test evaluation reports shall contain the following information:

- a. Test requirements, i.e., the environment under which the tests were conducted and the expected data from this environment.
- b. Test results, i.e., the actual data obtained from the test.
- c. Comparison between a. and b. In the case of deviations between a. and b., the reasons for the deviations shall be described and methods to improve the performance shall be recommended.
- d. Statement of accuracy of data.

APPENDIX A

DESCRIPTION OF LIQUID PROPELLANT SYSTEMS

Liquid propellant systems generally are identified as gas pressurized or pump pressurized systems, although in some cases, the system is identified by the type of propellants used. These may include hypergolic (ignition on contact), nonhypergolic (ignition required), monopropellant, or prepackaged propellants that may be either hypergolic or nonhypergolic. In addition, the propellants used will, in large measure, determine the tests performed and data obtained from the tests (e.g., hypergolic propellant spillage and leakage tests).

The basic difference between a gas pressurized system and a pump pressurized system (which comprise the two general types of liquid propellant systems) concerns pressure and volume. A missile with a gas pressure feed system requires as part of the system a large volume, high pressure source (receiver). A pressure-fed system utilizes gas pressure from the high pressure receiver, or from a gas generator system to feed the propellants directly to the combustion chamber. Gas pressure is regulated to produce the required pressure differential, and control valves are utilized to vary propellant flow rate.

A pump pressurized system requires less volume of high pressure gas than a gas pressurized system. In a missile with a propellant pumping system, gas is regulated into the propellant tanks to feed propellants at low pressure into the turbo pump which in turn increases the pressure to that required to feed propellants to the combustion chamber.

Tank construction varies considerably between the two systems. In the gas pressurized system, the gas tank and two propellant tanks are of heavier construction than in the pump pressurized system, to withstand the high pressure. In the pump system, the high pressure gas tank or tanks usually are spherical and the propellant tanks are of thin wall construction. The pump pressurized system weighs less and occupies less space than the gas pressurized system.

APPENDIX B

SPECIAL FACILITIES AND EQUIPMENT

A. Static Firing and Nonfiring Flow Test Facilities and Equipment

The static test stand for liquid propellant propulsion systems usually is of vertical construction with a thrust mount and tower of sufficient diameter and height to accommodate a complete missile, if such a test is required. (Static testing usually is conducted on the rocket engine only.) Propellants and other requirements (air, gas generant, etc.) for the test are normally supplied from permanently installed tanks.

A thrust frame or ring is a permanent part of the static test stand to which the motor thrust frame mounts. Between the thrust frame of the stand and stand main structure shall be mounted the sensing elements that record the motor's thrust. Calibration of the complete thrust measuring system shall be accomplished prior to any acceptance or other test when thrust measurement is to be part of the required data.

When a liquid propellant static test is conducted on a complete missile, the propellant tanks and gas tank of the missile will be used to supply propellants and high pressure gas. A set of propellant tanks of the same capacity as those of the missile shall be mounted in the test stand tower over the engine. These tanks shall be charged by the test stand's propellant storage tanks which shall be of sufficient capacity to supply propellants for several firings on the motor. These storage tanks usually are so located that it will be possible to fill the firing tanks by gravity flow.

Liquid propellant engine static testing facilities usually are built so that motors shall be fired in the vertical position with exhaust down. Some type of flame deflector shall be required to prevent erosion at the base of the stand restraining structure. Flame deflectors may be flat or dished open surfaces made from concrete or steel and are either water cooled, or not, depending upon the thrust rating, firing duration, elevation of the motor exhaust above the deflector, and exhaust gas composition. Some deflectors are of the water-cooled elbow design and deflect the exhaust gases a full 90 degrees. Elbow deflectors generally require a large amount of cooling water and are not considered economical, especially where process water is scarce.

The facility shall have ample water, not only for cooling purposes but for fire protection as well. The fire system shall be equipped for automatic as well as emergency manual activation.

Control centers at modern facilities usually are air conditioned because of the large amount of electronic equipment which they contain. Temperature control is essential for high accuracy as well as for personnel comfort.

The static firing test facility shall contain an automatic control console capable of turning on all instrumentation at a programmed time, firing the engine, and shorting the firing circuit. These events shall be completely automatic but manual control shall be possible at any time in the event of malfunction. Indirect vision through mirrors and/or closed circuit television

for test observation shall be common practice and two-way voice communication between the control center and the test stand shall be considered essential.

Data systems shall be connected through patch panels at both the transducer and recorder ends to provide flexibility in test setups. On-site oscillogram processing shall be provided for data reduction.

Supporting facilities such as machine shops, propellant storage, and supply rooms are required to prevent delays in test operations.

Ample electrical power shall be provided for both normal operation and excess load requirements.

A supply of high pressure inert gas such as nitrogen is needed for blanketing propellant tanks and for operating pneumatic valves.

Process water shall be ample for fire fighting and decontamination purposes in addition to all other requirements. Permanently connected and automatically controlled fog or spray nozzle systems are considered essential, as well as hand operated chemical extinguishers. Facilities shall provide remotely controlled, automatic, chemical fire fighting systems.

B. Hazard and Destruct Test Facilities and Equipment

Facilities to conduct hazard tests include an isolated area, preferably on flat ground, equipped with ample firm electrical power, an ample supply of water for fire fighting and decontamination, and a personnel shelter. In the absence of firm electrical power, gasoline or diesel generators shall be used. A communication network between the test site and base headquarters shall be established either by radio or telephone.

Equipment for conducting hazard tests shall be brought to the test site as needed. Motion picture cameras capable of a film speed of 1000 frames per second meet the requirements for the hazard tests. However, for photographing blast phenomena in case of detonation, cameras with film speeds up to 6000 frames per second are required. If possible, closed circuit television or microwave television systems equipped with zoom lenses should be employed.

C. Propulsion System Components Test Facilities and Equipment

These test facilities and equipment consist of the pneumatic, hydraulic, and electrical test facilities. The pneumatic and hydraulic test facilities are frequently used to calibrate flow meters and to set regulators. Accuracy of component testing is dependent upon the accurate calibration of the equipment contained in the test benches. Calibration of all measuring and recording instruments by a laboratory equipped with primary standards must be accomplished at regular intervals.

1. Pneumatic Test Facilities and Equipment

The major facility for pneumatic component testing is a flow bench which supplies a centralized distribution, regulation, and flow control point for high pressure gas, supplied by a large volume, high pressure, cascade system. Pressure, volume, and type of gas are determined by specifications

applicable to the systems to be tested. For convenience and efficient operation, the flow bench shall be divided into a high flow system and a low flow system. Incorporated within each flow system shall be regulators to control pressure over the entire available range, flow tubes (straightening vanes), and differential pressure transducers, and flow meters for measuring flow.

The pneumatic flow bench shall be a conveniently arranged assemblage of the apparatus required for accurately and efficiently determining the operating characteristics, calibration, reliability, and life of pneumatic components of missile systems. The bench shall contain all necessary instrumentation for controlling and recording pneumatic pressures and flows.

2. Hydraulic Test Facilities and Equipment

The hydraulic flow bench used for the testing of missile system hydraulic components provides a centralized controlled source of liquid flow and pressure.

For convenient and efficient operation, the hydraulic flow bench shall be separated into an oil flow system and water flow system. The range of flows and pressures must be known.

Incorporated in the bench shall be filters, flow meters, heat exchangers, weigh tank, timing clock, antifoaming storage tank, and all instrumentation for controlling and recording hydraulic pressures and flows.

3. Electrical Test Facilities and Equipment

The electrical test bench provides a centralized distribution sub-panel for the various types of electrical power that are required in evaluating and testing propulsion system electrical components.

The bench shall provide complete instrumentation for measuring and recording the performance of electrically driven rotary components, relays, solenoids, switches, instruments, signal devices, electro-mechanical servo-mechanisms, and similar missile equipment.